ASSIGNMENT # 4
ELEC 631 – Digital Filters: II

Due Date: October 14

1. An analog Chebyshev lowpass filter has a continuous-time transfer function

$$H_A(s) = H_0 \frac{1}{s + b_{00}} \prod_{i=1}^{2} \frac{1}{s^2 + b_{1i}s + b_{0i}}$$

where

$$\begin{aligned} H_0 &= 0.409513 \\ b_{00} &= 0.538914 \\ b_{01} &= 1.194937, \quad b_{11} = 0.333067 \\ b_{02} &= 0.635920, \quad b_{12} = 0.871982. \end{aligned}$$

The passband and stopband edges of the filter are 1.0 and 2.0 rad/s, respectively.

   (*a*) Derive expressions for the amplitude and phase responses of the filter. (**Hint:** See Sec. 10.2.5, p. 469-471, of textbook for relevant theory.)

   (*b*) Write a MATLAB program (*m*-file) that will plot the amplitude and phase responses of the filter.

   (*c*) Use your MATLAB program to plot the amplitude and phase responses over the frequency range 0 to 3.0 rad/s.

   (*d*) Use your MATLAB program to find (i) the filter gain at the passband edge, (ii) the filter gain at the stopband edge, (iii) the minimum passband gain, and (iv) the minimum stopband loss (negative of the maximum stopband gain).

2. Using D-Filter, plot the amplitude and phase responses in part (*c*) and determine the quantities in part (*d*) of Prob. 1.

   NOTE: D-Filter can be downloaded from

   http://www.ece.uvic.ca/~dsp/versions.html

   To install the program, a license number is required. One can be found on the D-Filter insert between pages 454 and 455 in Digital Signal Processing: Signals, Systems, and Filters.

3. A digital Chebyshev lowpass filter has a discrete-time transfer function of the form

$$H_D(z) = H_0 \frac{z + 1}{z + b_{00}} \prod_{i=1}^{2} \frac{z^2 + 2z + 1}{z^2 + b_{1i}z + b_{0i}}$$

where

$$
\begin{aligned}
H_0 &= 3.009606E-5 \\
b_{00} &= -8.427140E-1 \\
b_{01} &= 7.606568E-1, \quad b_{11} = -1.705365 \\
b_{02} &= 9.025560E-1, \quad b_{12} = -1.791814
\end{aligned}
$$

and the sampling frequency is $\omega_s = 20$ rad/s. The digital filter, like the analog one in Prob. 1, has passband and stopband edges at 1.0 and 2.0 rad/s, respectively.

(a) Derive expressions for the amplitude and phase responses of the filter.

(b) Write a MATLAB program (m-file) that can be used to plot the amplitude and phase responses of the filter.

(c) Use your MATLAB program to plot the amplitude and phase responses over the frequency range 0 to 3.0 rad/s.

(d) Use your MATLAB program to find (i) the filter gain at the passband edge, (ii) the filter gain at the stopband edge, (iii) the minimum passband gain, and (iv) the minimum stopband loss (negative of the maximum stopband gain).

4. Using appropriate MATLAB functions, plot the amplitude and phase responses in part (c) and determine the quantities in part (d) of Prob. 3.

   Some useful MATLAB functions are as follows:

   - Function impz computes the impulse response of a digital filter.
   - Function stepz computes the step response of a digital filter.
   - Functions freqz, angle, phasedelay, grpdelay, and unwrap can be used to compute the frequency, amplitude, or phase response, or delay characteristic of a digital filter.
   - Function freqs computes the frequency response of an analog filter.
   - Function fvtool is a very useful and sophisticated tool, very much like D-Filter, that opens a graphic user interface (GUI) and displays many useful things about a digital filter.

   See MATLAB Help for more information, for example, to get more information about fvtool use

   ```
   help fvtool
   ```

   on the command line.